Appendix D

Areal Time Series Precipitation Tools

Overall Function: This appendix describes the tools that should be provided in DDAP to compute mean areal precipitation (MAP) and to assist in determining average areal precipitation estimates using water balance computations (i.e. computations involving runoff and evaporation data in addition to precipitation data).

PETA Selection: When the Areal Time Series Precipitation category is chosen, the user should first be given a list of PETAs that exist for the Basin. The user will then choose the appropriate PETA. How the tools are applied will also depend on whether the HPOR is being analyzed or whether the record is being extended, thus the user will also need to select the period to be worked on from a list of available periods defined for the chosen PETA.

Basic Display: Once the PETA and the period of record have been selected, the basic display for the Areal Time Series Precipitation tools window should contain the following in addition to overlay, zoom, query, and units features:

- Basin boundaries - i.e. the overall boundaries of the Basin currently selected as specified in the Basin definition, and

- Watershed boundaries - for all watersheds currently defined for the Basin and PETA.

Menus: Control and Tools menus should be included. The Control menu only needs a Quit option. The tools menu should contain the following options:

- Compute MAP,
- Water Balance Summary,
- Watershed Average from Water Balance,
- Isohyetal Adjustment - Data Sparse Basin.

The capabilities that should be included for each of the Areal Time Series Precipitation tools are described in this appendix starting on separate pages.

Compute MAP

Function: To compute Mean Areal Precipitation (MAP) time series for individual Watersheds and also for zones within subdivided Watersheds.

Input: (all from previously stored information)

- List of Stations to be used (obtained from stations selected using the Station Selection tool described in Appendix C for the period chosen - list depends on whether the HPOR or an extension) - also observed data and meta data for each station,
- Indicator as to whether the Basin is to be treated as a mountainous or non-mountainous area (initially set when the Compute MAP tool is first used for the Basin),
- If a mountainous area, the consistency corrections defined for all stations using the Compute Monthly Means tool described in Appendix C that apply to the chosen period - also indicator as to whether corrections defined on an annual or seasonal basis and if so, the beginning month of winter and summer - also specification of how stations are to be grouped on the double mass plots,
- If a mountainous area, the mean monthly precipitation values for the HPOR determined using the Compute Monthly Means tool described in Appendix C - monthly means must be available for all stations (if not, they must be generated first),
- If a mountainous area, indicator as to whether precipitation is analyzed on an annual or seasonal basis defined using the Compute Monthly Means tool described in Appendix C (i.e. whether annual or seasonal station weights are to be used),
- If a mountainous area, isohyetal maps to use to compute average annual or seasonal precipitation (defined on a monthly basis) - isohyetal map used can be one of the following:
  - Base isohyetal maps - generally PRISM map,
  - Adjusted isohyetal maps - produced using the Isohyetal POR Adjustment and/or the Gage/Isohyetal Adjustment tools described in Appendix C, or
  - Data sparse areal isohyetal maps - produced using the Isohyetal Adjustment - Data Sparse Area tool described in this appendix.
- If a mountainous area, anomaly maps and/or correlation pattern displays produced using the Anomaly Map and Correlation Patterns tools described in Appendix C (optional), and
- If automatic station weighing is to be used (i.e. Thiessen or Grid Point weights), a boundary definition for each MAP area included.

User Specification:

- Indicator as to whether the Basin is to be treated as a mountainous or non-mountainous area (only input when the Compute MAP tool is first run for the Basin),
- Indicator as to whether station consistency is to be checked or MAP values are to be computed,
- If consistency is being checked and this is a non-mountainous area, an indicator as to whether the checks should be on an annual or seasonal basis and if seasonal, the beginning month of winter and summer - also specification of how the stations are to be grouped on the double mass plots (currently a max of 5 stations per plot) - values are input by the user when the Compute MAP tool is first applied to the Basin and selected PETA, after that the values

can be modified if the HPOR is being analyzed, but if the periods for which consistency corrections are applied are changed (i.e. start of winter or summer), all currently defined seasonal corrections should be removed,

- If a non-mountainous area, indicator as to whether precipitation is to be analyzed on an annual or seasonal basis (i.e. whether annual or seasonal station weights are to be used) and the beginning month or winter and summer - only input once either through this tool or the Watershed Average from Water Balance tool described in this appendix,
- If consistency is being checked and this is an extension period, the beginning date of the period to be run (can be prior to or equal to the start of the extension period),
- If MAP values are being computed, the watersheds to be included (user chooses from a list of all watersheds defined - list shows whether time series already exist for each watershed for the period selected) - if a watershed is subdivided, MAP values are automatically computed for all zones,
- If MAP values are being computed and the HPOR chosen, the type of station weights to use for all watersheds selected (Thiessen, grid point, or predetermined weights) - if an extension period, the station weighing method will be the same as used for the HPOR,
    - if Thiessen or grid point weights selected, boundary values must be available for all Watersheds and zones included (boundaries should be available for travel time zones but not for elevation zones),
    - if predetermined weights selected, the user inputs list of stations to be weighted and the relative weights (mountainous area) or actual weights (non-mountainous area) for each station (annual or seasonal weights), and
- Time interval of MAP time series if the HPOR - if an extension period, the time interval for each area should be the same as that used for the HPOR,

Method: In general the basic procedure is incorporated in the current historical data MAP program, however, some changes will be needed to that program when it is incorporated into DDAP. Some of the options to include when the program is incorporated into DDAP are:

- In all cases (i.e. whether consistency being checked or MAP computed),
    - Observation time changes defined in the meta data file for each station are used when reading daily precipitation values,
- If station consistency is being checked,
    - If a non-mountainous area,
        - If the HPOR - data are checked using IDMA type displays and interactive input of corrections,
        - If an extension period - IDMA method used but corrections can only be entered for the extension period,
    - If a mountainous area - begin with corrections determined using the Compute Monthly Means tool,
        - If the HPOR - IDMA method used and new corrections can be added or existing corrections modified,
        - If an extension period - IDMA method used but corrections can only be added or modified for the extension period,
- If MAP values are being computed,

◦ Computational period corresponds to the period chosen (i.e. HPOR or extension),
◦ If a mountainous area and if predetermined weights used, actual station weights are computed from the relative weights, station average annual or seasonal values (computed from mean monthly values), and areal average annual or seasonal amounts (computed from isohyetal maps using the Watershed boundary and zonal definition information) using Eq. 6-3-4 in the Calibration Manual - weights most likely will not sum to 1.0.

Displays Generated:

- Tabulation similar to that in the current historical data MAP program showing for each MAP area the monthly, yearly, mean seasonal (if seasons being used), and mean annual values, and
- Plot showing the accumulation of MAP values versus time for all areas.

Output: (after user Okays the results)

- Indicator as to whether the Basin is to be treated as a mountainous or non-mountainous area for this PETA (stored when the Compute MAP tool is first used for the Basin and specified PETA),
- MAP time series for the selected period for all specified Watersheds (time series for extension periods are appended to the existing time series for each Watershed),
- Update list that indicates for which Watersheds and periods of record MAP time series exist,
- If the HPOR,
  - Time interval used to compute MAP for each time series generated,
  - Type of station weights used to compute MAP for each time series generated,
- If a non-mountainous area and consistency is being checked, values defining whether the checks and any corrections are seasonal or annual and if seasonal, the beginning months of winter and summer, and how the stations are to be grouped on the consistency plots, and
- Any new values and updates to consistency corrections and how stations are grouped on consistency check plots.

Water Balance Summary

Function: To compute water balance information for selected Watersheds within the Basin.

User Specifications:

- Watersheds to be included in the computations - can be headwaters or local areas (historical mean daily flow data must exist for each watershed specified - for a local area, the mean daily flows are from the Local Area Flow Computation tool described in Appendix A),
- Historical streamflow time series to use for each Watershed when multiple time series exist (e.g. a given Watershed could have observed and adjusted time series), and
- The period of record to use for each Watershed - can vary from one Watershed to another (overall default is the HPOR - the default for each Watershed is the period for which historical streamflow data exist within the HPOR).

Input: (from previous stored information)

- Historical flow data for each Watershed (could be observed, computed local, or adjusted),
- MAP time series for each Watershed included (time series must exist for the period of record being used for each Watershed),
- Drainage area for each Watershed (use area input to the Watershed Boundaries tool as described in Appendix B rather than computed area),
- Mean elevation for each Watershed - if zones exist within a Watershed, the fraction of the Watershed area for each zone (from the Watershed Properties tool described in Appendix B).

Method: (For the period of record for each Watershed)

- Compute mean annual precipitation from the MAP time series - if zones, weight each zone by its fractional area,
- Compute mean annual runoff from the historical mean daily flow time series using the appropriate drainage area, and
- Compute mean annual actual evapotranspiration (ET) by subtracting the mean annual runoff from the mean annual precipitation.

Displays Generated:

- Table showing identifier, name, period of record, mean elevation, mean annual precipitation, mean annual runoff, and computed mean annual actual ET for each Watershed (similar to Table 6-3-1 in the Calibration Manual), and
- Plot of mean annual actual ET versus the mean elevation of each Watershed (similar to Fig. 6-3-5 in the Calibration Manual) - legend should identify each Watershed.

Output:

- Computed values and definition of time series for each Watershed. Subsequent use of the tool would start with this information. Values would be updated if time series altered (e.g. MAP recomputed or streamflow adjusted). Watersheds could be added or deleted, and
- Plot of annual actual ET versus elevation (only one such plot per Basin and PETA).

Watershed Average from Water Balance

Function: Derives an estimate of the long term average mean areal precipitation and actual ET for the HPOR based on water balance estimates for a specified Watershed. Typically used in data sparse regions where there is insufficient historical gage data to have confidence in the isohyetal analysis or the actual ET values computed by the Water Balance Summary appear unrealistic. Procedure described in Section 6-5 of the Calibration Manual under the heading Determining Precipitation and Actual ET from Runoff, Evaporation, and Vegetation Information and referenced in Section 6-3 under the title Determination of the Average Mean Areal Precipitation in Data Sparse Regions.

User Specifications: Information input when the tool is first used for a given Watershed within a selected Basin and PETA. If the tool is rerun for the same Watershed, the information from the prior application marked with an '*' can be modified.

- Watershed selection (historical streamflow data must be available at the outlet),
- Historical streamflow time series to be used (observed, local, or adjusted)*,
- Period of record to analyze (default is the portion within the HPOR for which flow data are available)*,
- If a non-mountainous area, indicator as to whether precipitation is to be analyzed on an annual or seasonal basis (i.e. whether annual or seasonal station weights are to be used) and the beginning month or winter and summer - only input once either through this tool or the Compute MAP tool described in this appendix,
- Specification of seasonal PE adjustment curve to use for the Watershed or each zone*,
- Assumed ratio of actual ET to ET Demand for the Watershed or each zone (user guess or based on a preliminary calibration of the watershed)*, and
- For watersheds with multiple zones, an indicator as to whether the distribution of precipitation over the zones will be based on user input or an isohyetal analysis (if user input, ratios of annual or seasonal zone precipitation to the Watershed average - if an isohyetal analysis, specification of which analysis to use)*.

Input: (from previously stored information)

- Mean Annual Potential Evaporation (PE) versus elevation relationship for the Basin (obtained from the PE versus Elevation tool described in Appendix G),
- Monthly Average PE for selected stations (obtained from the Compute Average Monthly PE option under the Compute Point PE tool described in Appendix G),
- Mean watershed elevation and if divided into zones, the fraction of the drainage area and mean elevation of each zone (from the Watershed Properties tool described in Appendix B),
- Isohyetal map covering the Watershed (either base map or adjusted) - defined on a monthly basis,
- Seasonal PE adjustment curves defined using the Seasonal PE Adjustment Curve tool described in Appendix G, and
- Mean daily flow time series for the Watershed.

Steps:

1. For the selected Watershed determine the average annual PE at the mean elevation of the drainage or the mean elevation of each zone (if divided into zones) from the PE versus Elevation relationship for the Basin,
2. Prorate the annual PE values into average monthly amounts using monthly distributions for stations in the area (user specifies station to use for the Watershed or each zone),
3. Subjectively assign seasonal PE adjustment curves to each zone based on vegetation information,
4. Multiply the average monthly PE values times the seasonal PE adjustments to get monthly ET-Demand estimates for each zone - from these monthly values compute the annual ET Demand for each zone,
5. Estimate the annual average actual ET by multiplying the user input ratio of actual ET to ET Demand times the annual ET Demand determined in Step 4 - If multiple zones, weight each actual ET value by the portion of the watershed that it represents to get the average actual ET for the entire watershed,
6. Compute average annual runoff for the Watershed from the daily flow time series,
7. Add the average annual runoff from Step 6 to the average annual actual ET from Step 5 to get the average annual MAP, and
8. If seasonal precipitation analysis or multiple zones exist, prorate the average annual MAP to obtain seasonal and/or zonal values using either an isohyetal analysis or user specified distribution.

Displays Generated:

- Plot of monthly PE values derived for the Watershed and the stations used to prorate the annual estimates to monthly amounts,
- Plot of seasonal PE adjustment curves for the Watershed,
- Plot of monthly ET Demand values generated for the Watershed,
- Table showing the zonal and watershed annual averages of PE, ET Demand, ratio of actual ET to ET Demand, actual ET, runoff (watershed only), ratios of zonal MAP to watershed average (if multiple zones - annual or seasonal), and MAP (annual plus seasonal if computed).

Output:

- User specifications marked with an '*' to serve as default values if the tool is reapplied to the Watershed, and
- Derived values of average MAP (annual or seasonal), annual ET Demand, and annual actual ET for the Watershed or each zone if multiple zones exist (include mean elevation of each zone).

Isohyetal Adjustment - Data Sparse Basin

Function: To adjust the existing isohyetal maps for data sparse regions using MAP and ET estimates derived using the Watershed Average from Water Balance tool described in this appendix. This procedure is not described in the Calibration Manual, but is referred to in Section 6-3 under the portion titled Determination of the Average Mean Areal Precipitation in Data Sparse Regions.

User Specifications:

- Watersheds within the Basin to be used (Watershed Average from Water Balance tool must have been applied to each),
- If multiple isohyetal analyses exist for the Basin, select one to use,

Input: (from previously stored information)

- Average MAP (annual or seasonal), annual ET Demand, and annual actual ET on a watershed or zonal basis and associated elevations for selected watersheds within the Basin as derived using the Watershed Average from Water Balance tool described in this appendix,
- Isohyetal map covering the Basin (either base map or adjusted) - defined on a monthly basis,

Steps:

1. Plot annual ET Demand and actual ET versus elevation for all watersheds (to determine if the relationships for all the watersheds are reasonable and consistent - if not, will need to modify using the Watershed Average from Water Balance tool),
2. Compute ratios of the average MAP (annual or seasonal) derived from the water balance analysis to the average MAP computed from the existing isohyetal analysis for each zone and plot the ratios versus the mean elevation of each zone,
3. Draw an average linear relationship (annual or seasonal),
4. Produce an anomaly map showing the deviations of each zone from the average linear relationship (deviations computed as the ratio computed in Step 2 divided by the ratio specified by the average linear relationship - values plotted for the area represented by each zone and not for a point location),
5. Generate an adjustment field for the Basin (could be automatically drawn with possible user modification),
6. Multiply adjustments by the average ratio defined by the elevation and the average linear relationship to get the total adjustment and then multiply that value by the isohyetal map amounts to get an adjusted isohyetal map for the Basin on an annual or seasonal basis, and
7. Prorate annual or seasonal adjusted isohyetal amounts by the monthly pattern defined by the existing isohyetal analysis to get adjusted monthly isohyetal maps for the Basin.

Output: Adjusted isohyetal maps for the Basin defined on a monthly basis (overwrites any previous map defined by this tool, but not adjusted maps produced by other tools).